of the overlying Cenozoic sediments of the continental rise has decreased the width of this Cretaceous abyssal plain by as much as 200 km.

Sediments of the continental rise range in thickness from about 3 km at the base of the continental slope to several hundred meters along the seaward edge of the rise where it joins abyssal plains. Through most of its length the sedimentary sequence is separated from the continental slope by an unconformity. Seismic-profiler data reveal many examples of deformation within the rise due to slumping and gravitational sliding. The lower continental rise hills located at or near the rise-abyssal plain contact probably are the toes of these structures.

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DEEP MIOCENE IN SOUTHEAST LOUISIANA

Deep Miocene sediments strike east-west across southeast Louisiana. Generally, regional dip and total thickness of sediments increase southward. Deep Miocene hydrocarbon traps include deep-seated and piercement salt domes, faultline closures, and combination structural-stratigraphic phenomena. Drilling below 15,000 ft indicates two major, distinct east-west trends in the southern parts of Terrebonne and Lafourche Parishes. The northern trend is essentially an alignment of faultline structures with upthrown and downthrown production; the deep producing sediments are in the strata of the *Cibides carstensi* zone. The southerly trend is a series of salt domes and related down-to-the-north faulting; deep production is downthrown and from the *Textularia* "L" zone. Recognition of these trends will become more difficult as they are extended.

Some deep tests have been disappointing failures because they were located on young structures. Others have found buried faults and related deep sandstone which encourage additional drilling. Production possibilities from stratigraphic pinchout traps have been indicated in several areas, but economic factors of deep drilling inhibit this type of hydrocarbon exploration.

The limits of deep Miocene prospecting and production are imposed by technological and economic considerations. Production has been found below 21,000 ft and sandstones capable of producing may be projected to 30,000 ft and deeper. Prospecting above 17,000 ft has proved to be profitable, but at greater depths the economic potential is reduced by greater risks and costs.

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PHYSICAL CHARACTERISTICS OF FLUVIAL DEPOSITS

The physical processes of sediment transport and deposition by confined unidirectional flow are produced only in a fluvial environment. The physical properties resulting from these processes provide unique criteria for recognition of fluvial deposits. Characteristic physical properties include (1) surface texture, (2) particle shape, (3) texture, (4) fabric, (5) sedimentary structures, (6) bedding, (7) sequence of structures, bedding, and textures, (8) scour surfaces, and (9) local and regional geometric patterns. Other aspects, including mineralogy, detrital clasts and fragments, physical character of the associated sediments, and fauna and flora, may aid in the identification of fluvial environments.

Point-bar deposits resulting from channel migration are the most commonly preserved type of fluvial sandstone bodies. These geomorphic features are nearly universal in all meandering streams, and they control clastic deposition. The commonly developed sequence of festoon, current-laminated, and ripple cross-bedded sedimentary units is developed in response to flow across point bars. Other types of fluvial sand bodies, such as those deposited in alluvial fans, braided streams, and deltaic distributaries, exhibit many fluvial characteristics, but they lack the sequence of sedimentary structures related to point-bar deposition.

Unidirectional currents produce characteristic grain-size distributions, which suggest a predominance of saltation and suspension modes of particle transport. Current transport produces elliptical-shaped particles with smooth surfaces. Detrital clay clasts commonly are preserved, many altered to clay-ironstone concretions. Minerals chemically stable in fresh, oxidizing, slightly acid water are commonly characteristic, such as kaolinite, feldspar, and ferric iron. The absence of other minerals such as calcite, glauconite, and ferrous iron compounds is significant.

The external geometry of fluvial deposits is probably the least characteristic physical attribute. Individual outcrops may not show channeling, and fluvial sand bodies may be of a blanket type. Boundaries of channels, however, show abrupt pinchouts, commonly within a few hundred feet. Trends of sand bodies in connection with paleocurrent and slope indicators provide strong supporting evidence for identifying fluvial environments.

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TECTONIC IMPLICATIONS OF STRUCTURES IN STRATIFIED SEQUENCES AT BASE OF PACIFIC CONTINENTAL MARGINS[1]

During the past decade many geo-scientific discoveries suggest that continental margins are regions of extensive thrusting. Seismologic data establish that earthquake hypocenters are contained in a tabular volume of rocks that plunges steeply landward below the seaward edges of continents. First-motion studies of these earthquakes indicate a convergence of continental and oceanic crusts. On land, coastal areas of extensive thrust faulting are becoming known. These data support the hypothesis of ocean-floor spreading which requires extensive thrusting of oceanic crust beneath the continents. This hypothesis and the seismologically defined thrust zone imply that profound compressional deformation should take place at the base of continental slopes.

Structures produced by compressional forces are not observed in seismic-reflection records of the sediments filling marginal trenches or in sediments tilted against the continental slope during development of the trenches. Continental rises also consist of undeformed strata. Only deformation from subsidence and slumping has been seen at the foot of the continental slope from southern Chile to the outer Aleutian Islands. The observations of little or no thrusting at the juncture of the upper continental and oceanic crusts are now numerous and well established. These data must also be

[1] Publication authorized by the Director, U.S. Geol. Survey.

considered in hypotheses that explain the development of continental margins.

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ECONOMICS, DECISION MAKING, AND EXPLORATION POLICY

The objective of exploration is to find petroleum and increase the company's reserves. To accomplish this goal, the company must utilize its resources (*i.e.*, money and personnel) in the most effective way possible. This might seem to indicate that, to accomplish this goal, exploration should be restricted to those areas in which the potential big fields (*e.g.*, offshore) are being discovered. This is incorrect, however, because a company has limited resources and may not be able to obtain favorable leases in such areas. If this is the case, any effort spent on these areas will be a fruitless dissipation of resources. This does not mean that a company should not compete in these areas, but rather that it should learn how and where it can compete effectively.

Independents do not face this problem because their resources are so limited they cannot have illusions about how and where to compete. Very large companies can overcome this difficulty by overbidding on areas of interest, thus insuring that they can obtain their goals. It is the companies which fall between these extremes which face the problems of how and where to compete.

In attempting to compete, most companies use the trial-and-error method and in the process dissipate resources which they cannot afford to expend. Another alternative is to use the computer. Algorithms have been developed to simulate decision making in conditions of uncertainty; some have been done concerning exploration and lease bidding. By use of this type of approach and adapting the *OR* method to the problems of exploration, a company can find how and where best to invest its resources.

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RIPPLE-DRIFT CROSS-LAMINATION IN TURBIDITES

Ripple-drift cross-lamination is the name given to a series of ripples which "climb upon the backs" of each other as a result of the addition of sediment from suspension during ripple migration. The type found in turbidites is characterized by continuity of lamination across the ripple system, changing composition of laminae from lee side (mud) to stoss side (silt and sand), and gradual upward decrease of ripple amplitude.

Geometric analysis has shown that the angle at which the ripples climb is a function of lamina thicknesses on the lee and stoss sides, the angle of the lee and stoss slopes, and the symmetry of the ripples. Computation of many angles of climb and different ripple geometries has shown that all three factors (thickness, angle, and symmetry) are equally important in determining the angle of climb. Field measurements of ripple-drift morphology in Ordovician turbidites of the Gaspé Peninsula, Quebec, indicate angles of climb from about 3 to 40°, with cosets of ripple-drift cross-lamination ranging in thickness from 4 to 37 cm. There is a direct correlation between coset thickness and angle of climb, and lee-side lamina thicknesses tend to be two to four times greater than stoss-side thicknesses. The factor controlling the angle of climb is the ratio of volume of sediment deposited from suspension to the volume of sediment moved on or very close to the bed and deposited on the lee sides. The velocity at which the ripples move downstream is also a function of the same ratio, plus a function of the hydraulic parameters controlling the formation of the ripples. Because of the complex interactions of these variables, it is not yet possible to estimate accurately the time taken for formation of the ripple-drift cosets. Crude estimates suggest a period of less than 1 or 2 hours for a coset 40 cm thick.

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SEDIMENTARY STRUCTURE ZONATION ON TIDAL LEVEES, ANDROS ISLAND, BAHAMAS

The natural levees of tidal channels on northwestern Andros Island, Bahamas, show how primary sedimentary structures record small-scale variations in elevation and lateral position on a tidal flat. These levees, like stream levees, are highest adjacent to the channels, crest less than 50 cm above mean high water, and slope gradually for 25–300 m into shallow subtidal ponds.

The most pronounced variation in sedimentary structures is between the well-laminated sediments of the levees and the bioturbated sediments of the pond. In the intertidal and subtidal ponds, browsing and burrowing animals completely destroy primary lamination, but the long periods of desiccation on the levees keep burrowers out of the sediments.

Within the levees there are three distinct zones: (1) the levee crest, 30–50 cm above MHW, adjacent to the channel has smooth, parallel laminations 1–5 mm thick; mudcracks, where present, are discontinuous; (2) the central part of the levee, 10–30 cm above MHW, has thinner laminations, mostly less than 1 mm, that are disrupted by shallow mudcracks 2–6 cm apart. Cornflake-size chips and larger clasts are abundant; (3) on the pond side of the levees, 0–10 cm above MHW, thin, crinkled laminations less than 1 mm thick alternate with thicker laminations that have a prismatic structure inherited from surface mats of the blue-green alga *Scytonema* sp. Small mudcracks (2–8 mm) disrupt the lamination.

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SURFICIAL ALTERATION OF PLEISTOCENE(?) LIMESTONE ADJACENT TO SALINE LAKES, ISLA MUJERES, QUINTANA RÓO, MEXICO

Two interesting rock types result from calichification and alteration of the weathered surface of bedrock limestone adjacent to shallow saline lakes on Isla Mujeres, Quintana Róo, Mexico.

Jet-black micritic limestone is produced on the periphery of the saline lakes, apparently as the combined result of calichification, blue-green algal penetrations, and sulfate-reducing bacterial action. Micrite layers are added by calichification. The black color is attributed to finely disseminated organic material and iron sulfide(?) produced by bacteria. Bacterial action not only may be partly responsible for the black color of the limestone, but also may account for the small amount